National Bureau of Standards

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TECHNOLOGY

A Three-Stage Nonmagnetic Mass Spectrometer

A three-stage nonmagnetic mass spectrometer, employing the principle of velocity selection, has been developed by Dr. Willard H. Bennett of the National Bureau of Standards.[1] In the new spectrometer a radio-frequency field replaces the usual magnetic field. Combining unusually simple operation with small size, light weight, and high sensitivity, the instrument has promising applications in several fields of science and industry.

In ordinary mass spectrometers a high intensity beam of ions is bent in the field of a large iron magnet, passed through a narrow slit, and then focused accurately on a narrow receiving slit. The nonmagnetic mass spectrometer uses neither bending nor focusing. Ions produced in the ionization chamber travel in parallel paths through the tube, a glass cylinder 8 inches long and 2 inches in diameter. Three sets of three tungsten-wire grids are spaced along the tube to form the three stages. A radio-frequency potential is applied to the middle grid in each stage. An additional grid, with a negative potential applied, follows the final stage and in the absence of r-f potential turns back any electrons that may have arisen anywhere along the tube. Following the final grid is a collector plate, whose potential is sufficiently positive to repel all but the desired positive ions.

The distances between grids and between stages are selected very accurately so that for any particular ion mass there will be a single definite frequency of the radio-frequency potential that can speed up ions of that mass as they pass through each stage. The increased speed of these ions enables them to overcome the opposing potential on the collector, whereas all other kinds of positive ions are turned back. Successive distances between stages must be chosen so that the r-f potential will complete an exactly integral number of cycles during the time it takes for an ion of the desired mass to travel between stages, picking up maximum energy in each stage. The best combination of these integral numbers for a three-stage tube turns out to be 7 and 5, and in actual operation the seven-and-five cycle tube has completely separated the isotopes of chlorine. From this observation it is estimated that a four-stage tube, using integral numbers 13, 11, and 7 should resolve masses differing by only 1 percent.

The spectrometer can make use of all the ions that can be made to emerge through a grid several centimeters in diameter, and a new kind of positive ion source has been developed to take advantage of this. A spiral filament delivers an ionizing electron current of 100 milliamperes through a double grid attached at one end of a hollow metal cylinder 3 centimeters deep. The far end is closed by a grid and near it is another grid at a negative potential that turns back all electrons and draws positive ions out from the cylindrical enclosure. At a pressure of 4×10^{-5} millimeters of mercury the source delivers a positive ion current of 100 microamperes.

[1] For further technical details on this work see, Radiofrequency mass spectrometer, by Willard H. Bennett, J. Appl. Phys. 21, 2 (1950).

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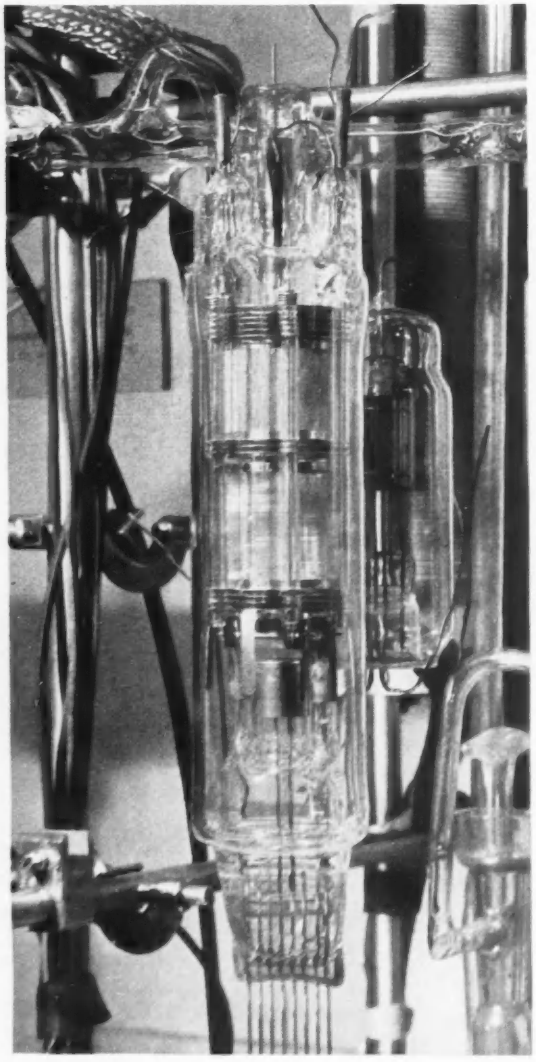
By an appropriate change in ion source and reversal of potentials, the spectrometer works well for the study of negative ions, an important feature of the new instrument. Since negative ions are in general much less abundant, when they exist at all, the unusual sensitivity of the Bennett spectrometer is a great advantage in the study of negative ions.

In the development of vacuum tubes, as for example power transmitting tubes, such a spectrometer can be very helpful in analyzing gases and vapors that are evolved from the heated electrodes.

Surface reactions are another group of processes for which the new spectrometer can be used, separately analyzing the positively or negatively charged components. In gaseous discharges, the instrument can be used for direct analysis of the ions without magnetically disturbing the discharge.



TECHNICAL NEWS BULLETIN

U. S. Department of Commerce

Charles Sawyer, *Secretary*

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E. U. Condon, *Director*

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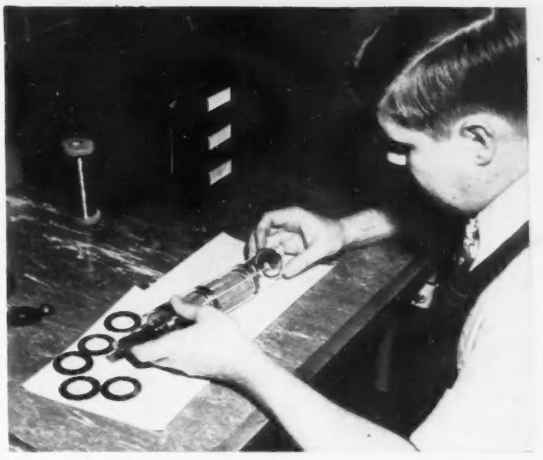
One of the urgent needs of the U. S. Bureau of Mines is an instrument that can be used in the field for the analysis of small percentages of hydrogen in the manufacture of helium. The new spectrometer has already demonstrated adequate sensitivity and resolution for this task, and it can be readily adapted to automatic operation. Similarly, the new instrument could be used for continuous observation of the air in an enclosed space, giving warning of the presence of dangerous components such as hydrogen or chlorine. In addition, an active project is now under way at the National Bureau of Standards to adapt this instrument as an extremely sensitive carbon monoxide detector.

The lightness and compactness of the nonmagnetic spectrometer offers a way to settle the question of the chemical composition of the upper atmosphere. This is a problem that is directly related to work in radio propagation and stratospheric flight. Arrangements have been made with the Applied Physics Laboratory of the Johns Hopkins University to send one of the new spectrometers aloft in a rocket. Before it is mounted in the rocket, the spectrometer tube will be evacuated and sealed; when the rocket has reached

This completed mass spectrometer tube shows the three sets of tungsten-wire grids. A radio-frequency potential applied to the middle grid in each stage speeds up ions of the desired mass enabling them to reach the collector.

Experimental models of the three-stage nonmagnetic mass spectrometer are fabricated by hand in the Bureau's physical electronics laboratory. Mr. Paul Martin is mounting the accelerating grid on the electrode assembly.



maximum altitude, an arm of the tube will be broken open to the rarefied air. The relative densities of atmospheric components will then be telemetered back to the ground for recording.

The nonmagnetic mass spectrometer is now being adapted to the rapid scanning of mass spectra. Present methods permit sweeping twice a second through the mass range from 10 to 50, displaying the measured mass components directly on the screen of a cathode-ray oscilloscope. The scanning is accomplished by sweeping the ion accelerating voltage from 50 to 250 volts while modulating the radio-frequency potential with a 1,000-cycle signal.

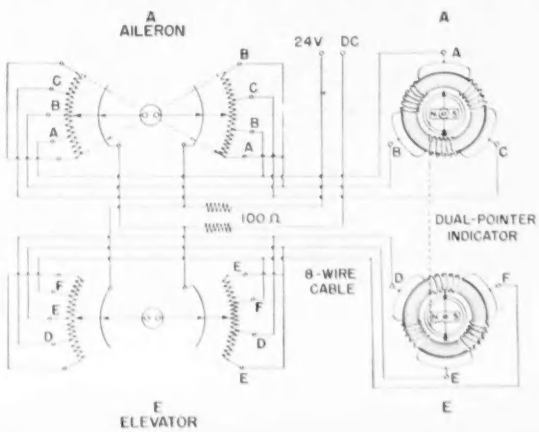
Stick-Force Indicator for Aircraft

An instrument that automatically indicates the force applied to the control stick of an airplane has been developed by F. Cordero and S. H. J. Womack of the Bureau's mechanical instruments laboratory for the Department of the Navy. The new instrument, which makes use of the flexure in a cantilever spring incorporated in the stick handle, is compact, easily attached to the aircraft, and requires little attention from the pilot. As it is unaffected by the ordinary fluctuations of aircraft battery voltages, is of adequate sensitivity, and permits the taking of a photographic record of stick-force indications, it is expected to aid materially in aircraft test work.

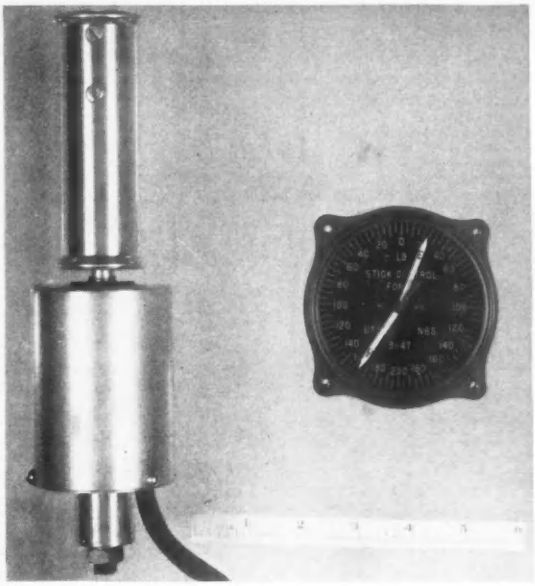
An important consideration in flight-testing new types of aircraft is the relation between the force applied to the controls by the pilot and the actual deflection of the controls in various maneuvers and at different air speeds. The force required of the pilot must not be so great as to prevent safe handling during any condition of flight. In many airplanes the principal control is a tube or rod extending vertically in front of the pilot and terminating in a simple grip, or handle. Sidewise movement of this device, known as the "stick," deflects the lateral or aileron control surfaces, whereas forward or backward movement governs the longitudinal or elevator controls.

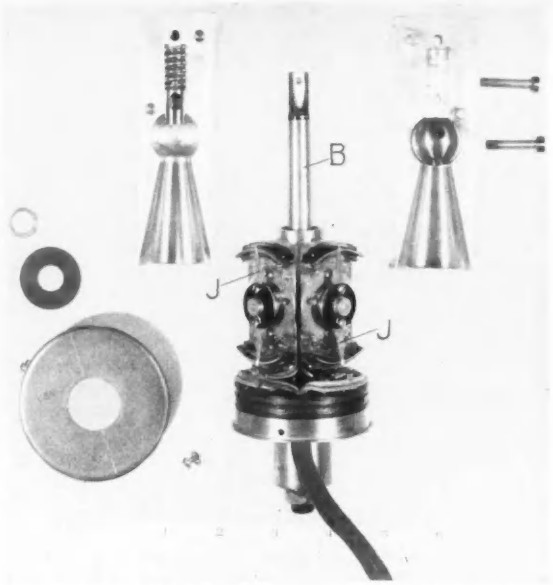
Until the NBS Stick-Force Indicator was developed, the two components of the force exerted on the stick were generally measured in one of two ways: either by pressing a single-component grip-type spring scale successively in the two required directions or by attaching strain gages to some part of the system used to transmit the control force. Both of these methods had their disadvantages. The first was inconvenient and distracting to the pilot, did not give simultaneous measurements of the two force components, and did not permit a permanent record to be made. Strain gages are still used and useful, but their readings are sensitive to voltage variations, and an amplifier is required if more than one indicator is used. The instrument developed by the Bureau, on the other hand, operates satisfactorily on varying aircraft voltages and makes possible a complete photographic record of the forces in the two required directions without disturbing the pilot in the normal operation of the controls.

In this device the standard stick handle is temporarily replaced by another containing the sensitive element, a cantilever spring whose deflection is measured in the two perpendicular directions. These deflections control electric voltages that operate a dual-pointer indicator of the direct-current selsyn type.



Schematic wiring diagram of the NBS stick-force indicator. Special selsyn transmitters operate ordinary selsyn indicators. Note the simplicity of brush contacts, each of which consists of two leaf-type springs, one contacting the voltage bar and the other the tapped resistance strip.





The NBS stick-force indicator measures the force applied to the control stick of an airplane at any instant. When the device (left) is substituted for the standard stick handle, the dial indicates the force required to operate the aileron control surfaces (pointer marked "A") and the elevators (pointer marked "E"). The partially disassembled view (right) shows cantilever spring rod (B) which acts in two directions to produce rotation of the brushes (J) of two direct-current selsyn transmitters. Electrical voltages from the brushes cause deflection of the two pointers.

The cantilever spring takes the form of a vertical rod of circular cross section, the lower end of which is held firmly as a post in the base of the unit. At the top of the rod a sphere is attached, and about the sphere is clamped the cylindrical handle, thus effectively localizing the application of force by the pilot at essentially one point. Flexure of the rod is then a measure of the transverse force exerted through the handle and spherical joint.

When the rod is bent by the application of a force at the handle, it deflects one or both of two flat spring strips mounted vertically beside the rod, attached at the lower end but free at the upper end to swing out with the rod as it bends. The flat strips are mounted in vertical planes that are at right angles, so that one strip is deflected by motion of the rod at right angles to that which deflects the other. Outward or inward motion of either of the strips moves a lever attached to the brush shaft of the corresponding selsyn transmitter, causing rotary motion of the brushes of the transmitter. The voltages thus produced are transmitted to two commercial direct-current selsyn indicators, which show motion in the two perpendicular directions. Both indicators are housed in one case having a single scale 360 degrees in extent and graduated directly in pounds of force. A second dual indicator may be connected in parallel with the first for duplicate indication. Since the deflection of the spring rod is proportional to the force applied to the handle, and since the rotation of the brushes [2] is nearly linear with respect to the rod deflection, a force indicator with essentially linear scale results.

When no force is being exerted on the handle, it is kept coaxial with the vertical rod by means of a coiled spring and plunger placed in a cylindrical cavity within the handle just above the sphere to which the handle is clamped. The handle is only bearing-tight about the sphere, which is screwed to the top of the rod. When the handle is displaced, the compressed spring presses the plunger down against a flattened part of the sphere and acts to return the handle to the neutral position.

The instrument constructed at the National Bureau of Standards is designed to measure a maximum force of 200 pounds in each of the two perpendicular systems separately, or a maximum of approximately 140 pounds in both systems simultaneously. A direct-current voltage between 22 and 28 volts is required, with a current of 50 milliamperes at 28 volts. An eight-wire cable connects the transmitter and indicator units. The circuit includes two 100-ohm protective resistors and four 7,500-ohm rheostat segments obtained from ordinary potentiometers, as well as four pairs of silver brushes and four contact bars of silver wire. The entire equipment, exclusive of electrical leads, weighs about 3 pounds.

The instrument is calibrated by hanging weights from the handle, held in a horizontal position. By changing the length of the lever operating the brush shaft, the calibration may be adjusted within a rather broad range. A special screw, slider, and drum are provided for making this adjustment, which may be conveniently performed after removing the case cover.

[2] The permissible motion of the brushes of each of the selsyn transmitters is 60 degrees. This compact form of selsyn transmitter appears to have been developed first by the Bell Aircraft Co.

Tests of a typical instrument show a maximum hysteresis of the order of 2 percent of full-scale value; thus the uncertainty in reading is about 1 percent of the full-scale range. The calibration curve deviates about 2 percent from linearity, and the sensitivity is of the order of 0.5 percent of the full scale.

Ceramic Thickness Gage

An electronic thickness gage for measuring the thickness of nonconducting coatings on nonmagnetic metals has been developed by Charles C. Gordon and Joseph C. Richmond in a project at the National Bureau of Standards sponsored by the National Advisory Committee for Aeronautics.[3] The new instrument provides a simple, direct, nondestructive measurement. These measurements have become important with the increasing use of ceramic materials as protective coatings for metals and alloys in high-temperature service. The new electronic gage can be used with nonmagnetic high-temperature alloys on which magnetic thickness gages cannot be used.

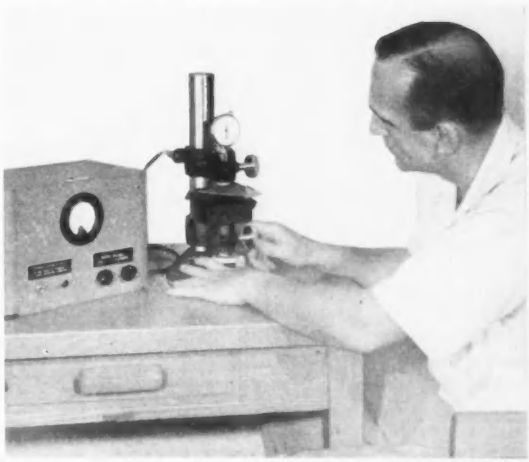
The instrument consists essentially of a small probe coil, an inductance indicating system, and a device for positioning the coil and measuring its distance from the test surface. The probe coil is housed in a cylindrical plastic test head. A small plastic rod attached to a dial indicator extends axially through the coil to serve as a feeler element. The test head is mounted in a heavy-gage stand that provides for controlled movement of the test specimen with respect to the probe coil. The electronic components of the 500-kilocycle oscillator and the bridge-type inductance indicating system are housed in a small cabinet and connected to the test head by a removable shielded cable. Bridge balance is indicated by a sensitive galvanometer. The measurement is based upon the change in inductance of the probe coil due to the proximity of the coated metal surface. This change may be visualized by considering the combination as a transformer with the probe coil as a primary coupled to the metal surface as a short-circuited secondary. The inductance of the primary varies with this coupling and hence with the proximity of the metal surface.

The instrument thus relies on the maintenance of a fixed distance between the probe coil and the metal surface whether the ceramic coating is present or not. The coating material has a negligible effect on the electric field at the frequency used; the metal surfaces are similar, so that their electrical properties are nearly identical. Under these conditions, if the inductance of the probe coil is the same in both cases, the separation distances will be equal, and the dial gage reading will give an accurate value for the coating thickness.

The ceramic thickness gage is designed to measure coatings up to 0.090 inch thick. For thin coatings, where the coil is within 0.020 inch of the metal surface, the sensitivity of the inductance bridge is about the same as the reproducibility of the mechanical dial gage reading. In this case, the thickness indicated on the dial gage is correct to within about 0.0002 inch. When the coil is 0.10 inch from the metal surface, readings may, however, be in error by as much as 0.001 inch.

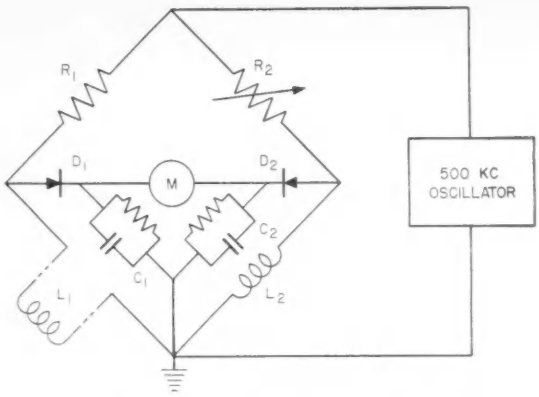
Before a thickness measurement is made, the instrument is calibrated on an uncoated specimen identical in size, shape, and composition with the coated specimen to be tested. The reference specimen is placed on the table of the gage stand, and the table is raised until the feeler of the dial gage is in positive contact with the surface. The dial gage is then set at zero, and the bridge rheostats are adjusted so that the galvanometer reading is zero. The inductance of the probe coil in the presence of the uncoated metal specimen is thus established as a reference value. The table is lowered and the uncoated specimen replaced by a coated specimen. The table is again raised until the galvanometer reads zero. The thickness of the coating is then given directly by the dial gage reading.

Independent tests have indicated that variations in size and shape between the coated and uncoated specimens are not important unless the thickness of either is less than 0.025 inch, the minimum width of either is less than 0.5 inch, or the measurement is made within 0.25 inch of an edge. For accurate measurements on curved specimens it is necessary that both reference and test specimens have the same curvature. It was also found that certain metals, which are themselves nonmagnetic or only weakly magnetic, produce magnetic scales when oxidized. The presence of any magnetic material in the coating or at the coating-metal interface will make accurate measurements impossible.



The new ceramic thickness gage gives a direct measurement of the thickness of nonconducting coatings on nonmagnetic metals. The instrument consists of an inductance indicating system, a small probe coil, and a device for positioning the coil and measuring its distance from the test surface.

[3] Further technical details on this work were presented before the 52nd Annual Meeting of the American Ceramic Society, April 24, 1950 (Enamel Division Paper No. 11 and will be published in the Journal of that Society.



In the ceramic thickness gage, a capacitor, C_1, and resistor in parallel are connected in series with crystal diode, D_1, and this in turn is connected across the probe coil, L_1. Since the current in L_1 is determined by series resistance R_1, the voltage across C_1 is proportional to the inductance of L_1. A comparison voltage is provided by reference coil L_2, connected in a similar circuit through variable resistance R_2, which is adjusted to give a zero reading on the bridge galvanometer, M.

The impedance bridge used in this instrument is particularly suitable, since variations in the inductance of the probe coil are indicated without separate balancing of resistive and reactive components at the bridge voltage. This is an advantage in thickness measurements because reactance variations are usually much larger than the accompanying resistance variations.

The bridge circuit is energized by a 500-kilocycle oscillator employing a dual triode in push-pull. A peak-reading rectifier circuit, consisting of a crystal diode in series with a capacitor and resistor in parallel, is connected across the probe coil. The direct-current voltage appearing across the capacitor is essentially equal to the peak alternating-current voltage drop across the probe coil and, since the probe-coil current is determined principally by a large series resistance, this voltage is effectively proportional to the inductance of the probe coil. In order to obtain a comparison voltage with the same sources of extraneous variation as the probe voltage, a reference coil is arranged in a similar circuit and fed from the same oscillator through a variable resistance, which may be adjusted to equalize the alternating-current voltage drops for both coils. The sensitive galvanometer, protected against overload by two crystal diodes in shunt opposition across the meter, indicates any unbalance between these two branches of the bridge.

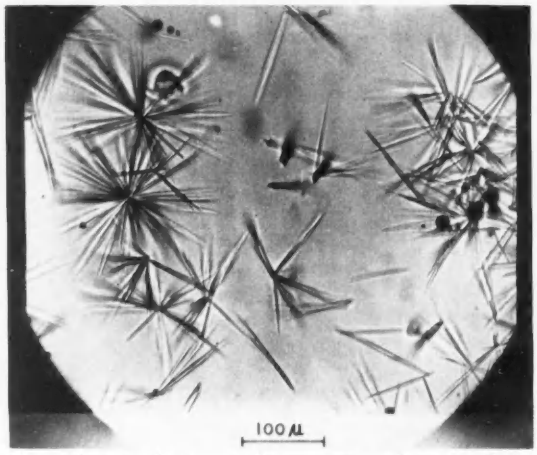
Although this instrument was developed primarily for the measurement of the thickness of ceramic coatings on turbine blades and other high-temperature parts of aircraft power plants, it should be generally useful for thickness determinations of paint, plastic, and other nonconducting films on aluminum, brass, copper, stainless steel, and other slightly magnetic or nonmagnetic metals.

New Method Studies Crystallization in Glasses

A rapid, convenient method for determination of the liquidus temperature and rate of crystal growth in glasses has been developed by O. H. Grauer and E. H. Hamilton of this Bureau. The technique [4] is simple and easily mastered, making it possible for an inexperienced operator to determine quickly data that formerly required much time and skill. It thus provides the glass technologist with an effective means for assessing the effects of changes of composition on the stability of the glasses.

In the development of new glass compositions at the Bureau, the most important limitation has been the possibility of devitrification, or the formation of crystals in the glass, at high temperatures. When this occurs, the usual result is a semi-opaque mixture of glass and crystals instead of a highly transparent and homogeneous glass. Even in the relatively stable glasses now in use, devitrification may take place during manufacture if the glass is kept too long at certain high temperatures.

Two properties of a glass that greatly influence devitrification are the liquidus temperature, or the highest temperature at which the molten glass can exist in equilibrium with crystals, and the rate of crystal growth. Most of the methods used to determine these properties have involved repeated heatings at different temperatures until the liquidus temperature is reached. The Bureau's method, on the other hand,



Photomicrograph of crystals grown in a glass sample by heating for 13 minutes at 838° C.

[4] For further technical details, see An improved apparatus for the determination of liquidus temperatures and rates of crystal growth in glasses, by Oscar H. Grauer and Edgar H. Hamilton, J. Research NBS 45, 395 (1950) RP2096.

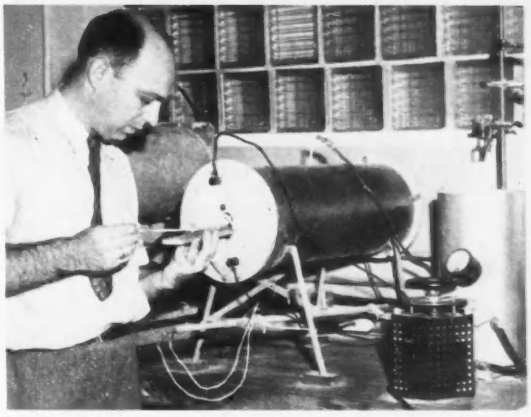
employs only one heating in a special platinum alloy apparatus within a gradient furnace. Thus it permits the rapid accumulation of data. This new procedure was developed for an intensive study of devitrification in glasses in order to facilitate the making of new types of optical glass having highly specialized properties. It is expected to aid materially in the development of new glasses and in solving problems arising in the manufacture of commercial glass articles.

In the method developed at the Bureau, small glass fragments are placed in indented cells spaced at regular intervals along a channel-shaped platinum-rhodium strip. The strip is then inserted in a horizontal tubular furnace in which is maintained a uniform temperature gradient. Because of the small mass of the specimen and its intimate thermal contact with the platinum-alloy cell, equilibrium is quickly attained. After an appropriate time interval, depending on the composition of the glass, the strip is air-quenched by rapid removal from the furnace. The contents of each cell are examined with the petrographic microscope, using light transmitted through an opening in the bottom of the cell. The last cell in which crystals appear locates the position in the temperature gradient corresponding to the liquidus temperature. Rate of increase in the crystal size is determined by measuring the crystals with a filar micrometer at intervals during the period following removal from the furnace.

The platinum-rhodium strip used at the Bureau is 5½ inches long and ½ inch wide. The cells are 1 millimeter deep and are tapered from an opening 2 millimeters in diameter at the top to a diameter of 1 millimeter at the bottom. At one end of the channel the cells are spaced ¼ inch between centers in a single row along the length of the strip, providing a temperature difference between cells of 20 degrees centigrade. At the other end of the channel the cells are spaced in two parallel rows 3/16 inch apart. In each of the parallel rows the cells are separated by ⅛ inch from center to center, but since one row offsets the other by 1/16 inch, the distance along the channel between centers of succeeding cells is only 1/16 inch. In actual operation, the holder is so placed in the temperature gradient that liquidus temperature is determined within the closely spaced cells of the parallel rows, and measurements of crystal size are made within the cells of the single row.

The tubular furnace consists of two concentric, grooved Alundum cores separated by insulation and encased in a larger steel shell that is packed with diatomaceous earth to reduce heat loss. The inner core is wound with platinum—20 percent rhodium wire along a central zone for a distance of 6 inches, and the outer core is wound with a nickel-chromium alloy wire along 20 inches of its length.

Temperatures within the furnace are measured with a movable platinum–platinum-rhodium thermocouple. By adjusting the current in both windings with small variable transformers, an almost linear temperature gradient is obtained. The maximum temperature of the furnace is held constant within 2 degrees centigrade by means of an electronic controller operating on a thermocouple located in the hot zone. This results in a stable gradient in the remainder of the furnace.



For studies of crystal formation in glasses, small fragments are placed in cells along a platinum-rhodium strip, and the strip is heated in an electric furnace. The temperature of the furnace varies along its length. After suitable intervals, the specimens are air-quenched and the contents of each cell are examined microscopically to determine the behavior of the glass at each temperature.

Good agreement has been obtained between results by this method and those obtained by the classical quenching method. The greatest deviation for a series of determinations on five different glasses was 6 degrees centigrade. Errors in other gradient methods due to flow of molten glass, slow quenching, and difficulty in locating the crystal boundary are largely eliminated. Since the entire apparatus can be placed on the microscope stage and the glass samples examined directly, positioning errors due to a broken glass specimen are also avoided. The method has proved to be very useful in the solution of devitrification problems arising in the production of large slabs of glass for interferometer plates in the Bureau's experimental glass plant.

Nickel and Its Alloys

A new circular just published by the National Bureau of Standards is a systematic and readily accessible summary of information about nickel. This circular combines information obtained by the Bureau in its own investigations with that available in published records of work done elsewhere. Particular attention is given to the physical and mechanical properties of nickel and its ferrous and nonferrous applications. Sources; extraction, recovery, and refining processes; metallography; chemical, physical, and mechanical properties; and other miscellaneous properties are given. Many ferrous and nonferrous alloys are listed, and their properties such as density, thermal conductivity, tensile strength, magnetic properties, and corrosion resistance are discussed. The text is adequately illustrated with curves and tables.

Circular 485, *Nickel and Its Alloys*, 72 large pages, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., for 50 cents a copy.

All navigators know that there can be no complete, all-purpose navigational system. The multiplicity of factors entering into navigation precludes this. The situation arises in part from the practical aspects of navigation, in which human judgment, on the basis of available information, must decide on one of a number of possible courses of action and partly because of the positional and directional data, meteorological and radio conditions, and equipment performance and reliability. If one adds to these the interrelationship of, say, a number of aircraft engaged in landing, taxiing, and take-off operations at an airport, it is apparent that the problem is a complex one. As higher and higher speeds are attained, an already difficult problem becomes exceedingly formidable, not merely in terms of airport control of traffic but of flight in itself. Moreover, the navigators of vessels at sea also have problems varying in complexity.

Current problems in navigation merit emphasis for at least two reasons: First, to suggest the urgent need for sustained and vigorous attacks on these problems; second, to indicate why many agencies of the Government and many industries and private laboratories have contributed extensively over a period of years to developments in this field. This report is concerned with the activities of the National Bureau of Standards in navigation.[5] These have included projects sponsored by many agencies of the Government—the Army, Navy, Air Force, and Civil Aeronautics Administration in particular—and have involved close cooperative relationships with nongovernmental organizations.

The work of the National Bureau of Standards may be grouped into three categories. First are aids to navigation. Here fall the primary aids to navigation, both electronic and nonelectronic, and the secondary ones such as aircraft and airport lighting insofar as they enter into the picture. Second is the role of basic measurements and the associated developments and services that stem out of that role. And finally, there are current problems associated with present and coming aspects of navigation.

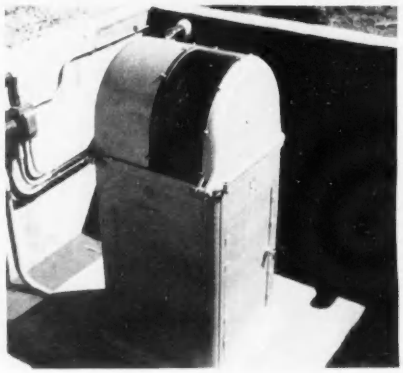
Aids to Navigation

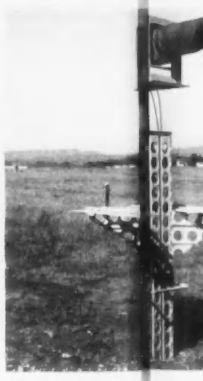
The scope of the Bureau's work in the field of aids to navigation is familiar to many. In the late 20's and early 30's the Bureau maintained the principal laboratory for the development of radio aids to air navigation for the Department of Commerce. This period saw the completion by the Bureau of most of the basic systems, developments upon which present air navigation systems are based.

As early as 1913, the Bureau had suggested that radio be used as an aid to navigation. Work was done in this area prior to the first World War, but for military reasons the information was not released until 1922. What had been achieved was, in brief, a practical form of direction finder for use on shipboard. The system makes use of directional antennas (which

[5] Substance of this article was presented by Dr. E. U. Condon, Director of the National Bureau of Standards, at the Eastern Regional Meeting of the Institute of Navigation, February 10, 1950.

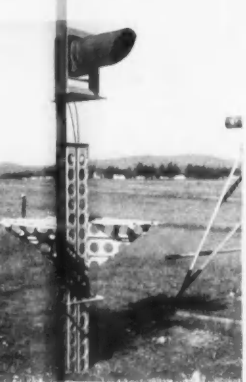
NBS Research in

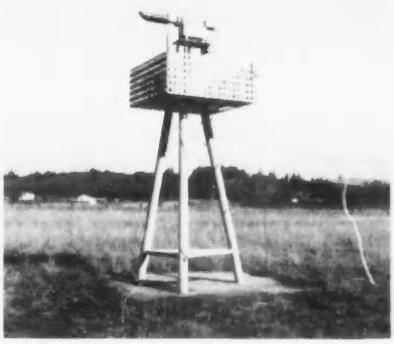




For many years the Bureau has participated in the develop and f perimental aids to navigation. The more recent work has cond Calif., (above). The instrument landing system, based o origin region where landing can be completed by the approach lig syste ures cloud-layer height; the NBS transmissometer (transm, cente by Landing Aiperime

earin Navigation





development and field testing of approach and runway lights and other ex-
work has conducted at the Landing Aids Experiment Station, Arcata,
based on original Bureau development, is used to guide planes into the
proach light system. Below: The Weather Bureau ceilometer (left) meas-
transmitter, center, and receiver, right) determines fog density. (Photos
ding Experiment Station.)

may be unidirectional) to take bearings on two or more points (e. g., shore stations), from which bearing signals are transmitted. By simple triangulation procedures, the precise location of the ship carrying the direction-finding equipment can be ascertained. The use of radio direction finding on this principle has been universal, and the basic principle is found in present radio compasses.

Since about 1928 radio beacons have been used to mark the airways of the United States. The method was first proposed by the Bureau in 1924. It is the method of interlacing signals on two loops of a figure-eight pattern in such a manner that a craft-on-course will receive equal signals from both loops. Experimental beacons were constructed by the Bureau, and from this work stems the present world-wide system of radio beacons.

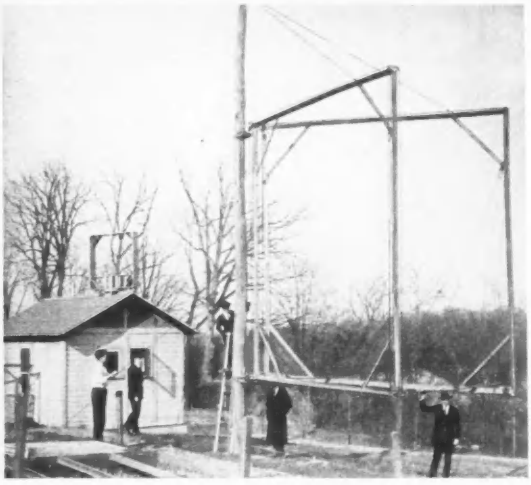
Related developments in this period were (1) a method for elimination of range beacon night errors, which was universally adopted; (2) a visual radio range beacon (the first models depended on aural signals); and (3) multicourse range beacons. In addition, substantial contributions were made in the design of aircraft receivers and antennas.

About 1929 NBS scientists proposed and developed a radio guiding beam for instrument landing; by the end of 1933 they had demonstrated the first complete system for blind landing of aircraft. The system includes radio-beacon transmitting equipment at airports, together with suitable receiving and transducing equipment in aircraft. There are three elements in the system that indicate to the pilot the position of the aircraft as it approaches and reaches the instant of landing: Lateral position, provided by a small directive beacon; longitudinal position, provided by a marker beacon; and height, provided by an inclined UHF radio beam. Devised by the late Harry Diamond, jointly with Francis W. Dunmore, the system not only increased by a large factor the safety of landings but also made it possible for aircraft to operate under conditions of visibility that would otherwise have made flight impossible. Adopted and adapted by the Civil Aeronautics Administration, this, the first radio instrument-landing system, is basic to the present universally used ILS blind landing system.

In addition to the development of these and related primary aids to navigation, the Bureau has made rather large contributions in the field of secondary aids. Examples include work on lighting, ceiling- and visibility-measuring instruments, chronometers, and compasses.

Thus, the Bureau has assisted C. A. A. in the development, and in laboratory and field testing, of approach-light systems from the time these lights were first considered. Similar work has been the development of airway beacons and course lights and of position lights—formerly called navigation lights—which are used to identify the course and position of aircraft to other aircraft. Two immediate problems are suitable lighting for helicopters and carrier approach lights for carrier-based aircraft.

The accurate measurement of ceiling and visibility is often an important element in safe landings. During



The equisignal radio range, now in general use by all commercial airlines to guide planes along the air routes, was first set up and tested at the National Bureau of Standards in 1921. The photograph shows the original dual-coil antenna system used to produce the on-course equisignal zone in space.

periods of restricted visibility, electronic aids are used to bring aircraft sufficiently close to the runway so that visual aids may be used to complete the landing. Experience in the Berlin Airlift showed the need for accurate measurements of the visibility and ceiling along the active runways. Measurements taken at a weather station sometimes as much as 2 miles away do not always give a true picture of the runway conditions. To cope with this problem, the Armed Services, the Civil Aeronautics Administration, and the Weather Bureau are planning operational tests of instruments to measure ceilings (the ceilometer) and visibility (the transmissometer) in landing areas. The ceilometer was developed by the Bureau for the Weather Bureau several years ago, and development of the NBS transmissometer was sponsored by the Civil Aeronautics Administration and the Navy's Bureau of Aeronautics.

Instruments of both types are now being used as controls in the extensive tests of lighting systems and fog-dispersal systems now being conducted at the Landing Aids Experiment Station, Arcata, Calif. Remote-recording equipment is installed on these instruments. During tests they provide a continuous record of the ceiling and visibility conditions of fogs in the critical locations. The instruments also give personnel in the control tower a much better idea of the conditions existing throughout the approach zone and along the runway than would be obtained by visual observations.

Two new types of compasses have been worked out in cooperation with the Navy Department. In one of these, eddy-current damping is substituted for the troublesome liquid damping. This compass appears to be limited to small sizes. It has been designed to serve as standby in the event that the electronic types fail and for use on abandoning aircraft over ocean or waste areas. The other is the sky compass, which is based on the work of the late A. H. Pfund of Johns Hopkins. The sky compass utilizes the direction of polarization of the light of the sky with reference to the sun. If the clear sky is illuminated by sunlight, even after sunset, the sun's azimuth can be determined by the instrument, and the direction of flight can thus be established. This compass is clearly of importance in polar navigation where the magnetic compass cannot be used.

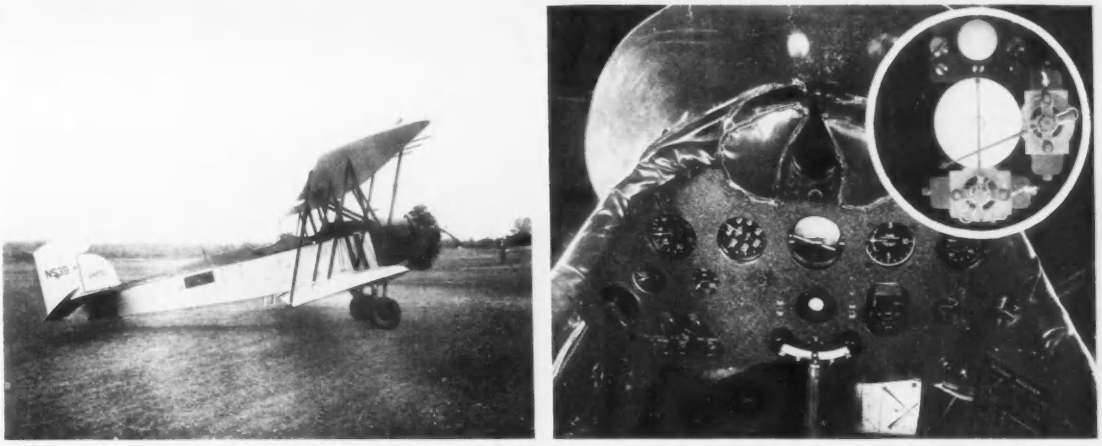
The significance of these developments and similar ones that have not been mentioned is obvious. Such systems as ILS and aural and visual radio ranges and beacons are now so integral a part of modern navigation, and their technical aspects are so familiar that a detailed description of their properties, advantages, and limitations is unnecessary. That these developments are obvious, however, in no way minimizes the magnitude of the contributions of their inventors and developers—men like Kolster, Diamond, Dunmore, and associates who pioneered in this work at the Bureau.

Basic Measurements

Perhaps less obvious than these particular systems, but of greater fundamental importance, is the indebtedness of navigation to basic standards and methods of measurement. Certainly the necessity for precise measurement in navigation need not be stressed. At the same time it is evident that such precision stems from and is directly related to the fundamental and applied research of the Bureau in the broad field of measurements.

This is evident when it is considered that most aids to navigation rely on three relationships: Velocity, time, and distance; and even an instrument such as the magnetic compass depends on accurately machined parts. The importance of precise length measurements is emphasized by the fact that accurate mapping of the

The magnetic eddy-current-damped compass consists of two Alnico V magnets fastened to the compass card, which are used as the direction elements. Damping of the magnets is secured by eddy currents generated in a surrounding copper cup.



This Curtiss Fledgling, equipped in 1931 with the first complete system for blind landing of aircraft using a landing beam, demonstrated the practicability of the system by a series of hooded landings. The dual-pointer landing indicator on instrument panel (enlarged view, right) gave the pilot a visual indication of his approach position. Adapted by CAA, this NBS radio instrument landing system is basic to the present ILS.

earth's surface is essential for navigation. This is a function of the Coast and Geodetic Survey, in which the Bureau has assisted by calibrating geodetic tapes and level rods, checking the accuracy of mapping scales, graduating the precise circles for theodolites, and graduating the precise master plates for reproduction of the compass roses found on all maps used for navigation.

The Bureau's work on time has also been important. As to instruments, for example, the Bureau has contributed to the development of precision chronometers, while the standard time and frequency signals broadcast continuously by radio stations WWV, in Maryland, and WWVH, in Hawaii, are playing an important part in navigation and communications.

Length, mass, time, electricity, magnetism, light, or any other topic or field of science that enters into navigation, involves in the last analysis, measurement. Basic measurement, methods and instruments of measurement, properties of materials, and physical constants constitute the basis of both pure and applied science. The scope of the Bureau's efforts in these directions is indicated by the 13 scientific and technical laboratory divisions: electricity and optics, metrology, heat and power, atomic and radiation physics, chemistry, mechanics, organic and fibrous materials, metallurgy, mineral products, building technology, applied mathematics, electronics, and radio. Even where the relevance of the general activity of one of these divisions appears indirect when thinking solely of navigation systems, it turns out that the practical, industrial manifestation of those systems depends directly or indirectly on results developed in every one of these major areas. For in these practical terms, it is necessary to consider not only the theoretical aspects of the system but also problems of materials—a wide range of materials and a wide range of operating conditions (which require extensive knowledge of the properties of these materials under varying conditions, for example, of temperature, humidity, shock, and vibration). If these considerations are ignored, the best theoretical system will end in failure.

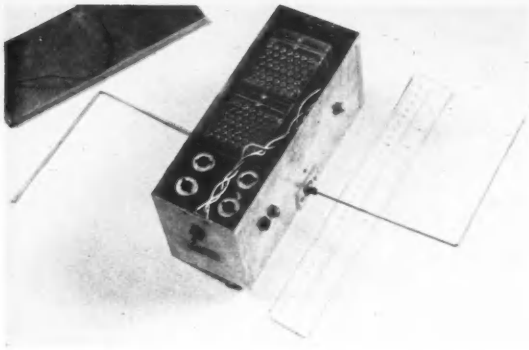
Two examples of work of this type are the Bureau's tube research program, which has as one of its objectives the development of more reliable electron tubes, and the miniaturization program, which has as its objectives the reduction in size and weight of electronic communication equipment and the development of unit assemblies designed to simplify maintenance. Both of these programs have been sponsored by the Armed Services—in particular the Navy. Progress has been attained in each program—typified by recent miniature and subminiature developments of i-f radar strips for the Navy.

The work of the Bureau may thus be characterized somewhat as follows: Specific navigation problems have been carried out, such as those that have been mentioned. Particular applications of the Bureau's effort in the broad field of basic measurement and instrumentation, of properties of materials, and of physical constants, have contributed directly to problems of navigation. And the broad, general work of the Bureau in measurements, standards, and instrumentation, has established the foundation for much other work in navigation—as it does, in fact, for technology as a whole.

Current Problems

In the course of this work, research, development, engineering, calibrations, testing, and specifications are related aspects, and very often one of these functions leads imperceptibly into another. Three large programs of the Bureau are among those pertinent to current problems. Two of them are concerned with radio propagation; one of them with information processing.

Radio communication and radio navigation are complicated by the great variability in behavior of radio waves. Broadly speaking, the properties of these waves



This balloon-borne instrument was developed for use with radar equipment to determine wind velocity and direction. The device, which can be tracked for distances up to 100 miles, consists of a receiver to pick up the radar pulse signal and an oscillator to return a pulse to the radar.

depend upon their frequency, and these properties are also subject to modification by the environment in which the waves find themselves. For long-range communication and navigation, the variable factors associated with the ionosphere enter into the picture—a large problem involving the sun's normal radiation, sunspots, the earth's magnetic field, and ionospheric storms. As a result, long-range radio navigational systems and aids are subject to error, both predictable and unpredictable, which must be realized and allowed for in their design and selection. In this field also, the Bureau has assisted by making propagation and comparative performance analyses of various systems. Then there are problems more closely related to the earth, such as ground effects, variability of terrain, and weather.

The difficulties inherent in this situation led, during the war, to a joint ionospheric program, conducted by the three Armed Services and the National Bureau of Standards; this activity was formally established by these groups at the Bureau after the war. One of the important activities in this area, of a practical nature, is the gathering of ionospheric data from the Bureau's 14 field stations here and abroad and from cooperating stations, both domestic and foreign. Analysis of these data leads to the publication of the Basic Radio Propagation Predictions, which predict 3 months in advance, for a 1-month period, the best frequencies to use for effecting communication between any two points on the surface of the earth. Valuable though this service now is, the nature of the problem is such that continued and intensive research is being carried on that should lead to better methods of prediction and thus to better predictions, which in turn will make possible more certain communication and navigation.

One of the aspects of this propagation work that is of immediate interest deals with determining the accuracy and reliability of radio navigation systems. The Air Navigation Development Board has therefore asked the Bureau to initiate a comprehensive investigation of the propagation characteristics of the band of frequencies in the neighborhood of 1,000 megacycles. This band has been designated for the development of the Common System of Air Navigation and Air Traffic Control. The primary purpose of the study will be a determination of the minimum spacing between stations, operating on the same or adjacent frequencies, which is permissible to prevent mutual interference. Furthermore, studies will be made of the multipath propagation conditions that may be encountered on these frequencies. This multipath study will determine the limits of the communication band that may be transmitted over a given channel without distortion.

In the inital phases of this program, the Bureau is simulating an air-to-ground transmission path by locating a transmitter on the top of Cheyenne Mountain near Colorado Springs. The transmissions are to be made over the plains to the east of this mountain. Receivers will be located at a series of points ranging from about 50 to 250 miles from the transmitters. It is believed that this is the first instance in which comprehensive propagation studies will have been made in a new band of radio frequencies prior to the investment of large sums in equipment intended to operate in the proposed band. By means of these propagation tests, it is hoped that difficulties of allocation and equipment design can be foreseen and allowed for in the early stages of development of the Common System.

The radiosonde telemeters data on upper-air pressure, temperature, and humidity from a balloon. This device, developed in 1936, employs an ultra-high-frequency oscillator and a modulator. The frequency of the modulator is controlled by special resistors whose resistance varies with the atmospheric phenomena.

Finally, there is a problem that is of great concern to every agency of the Government and every industry concerned with aviation: the general problem of air control. The Bureau is not at present engaged directly in this field, but is contributing indirectly through the design, construction, and procurement of automatic electronic computers, because it is apparent that a solution of the general problem will involve some modified types of equipment along these lines. Five machines of this type have been contracted for from industry, while two experimental machines are nearing completion at the Bureau's laboratories in Washington and Los Angeles.

Five sets of problems in this field have received particular attention by the Bureau. Two of these relate to the machines as practical, real instruments: overall design and the development of components. Three are related to the utilization of these machines: the mathematical-logical aspects of their design in terms of their uses, their application to purely mathematical or physical problems, and their application to information handling and processing.

Out of this program—the like of which probably exists nowhere else—the National Bureau of Standards expects to obtain data, components, and experience directly applicable to the design of air-control equipment. This will evolve inevitably out of the very nature of the present program. At the same time, the Bureau hopes to make contributions of a more definite kind in the design of air-control equipment: how far it is possible to proceed in this direction will depend on those Government agencies directly responsible for navigation *per se*.

Alloys of Phosphorus With Cobalt or Nickel

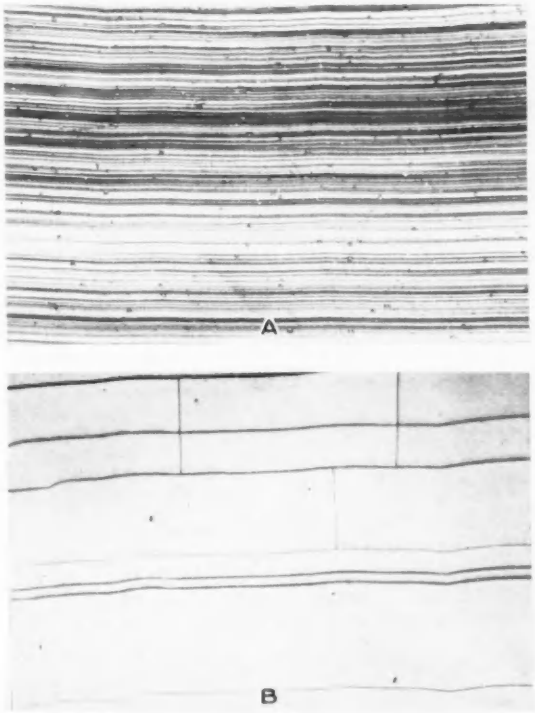
A commercially feasible method for producing electrodeposits of cobalt or nickel alloyed with as much as 15 percent of phosphorus has been developed by Abner Brenner, Dwight E. Couch, and Eugenia K. Williams of the National Bureau of Standards.[6] The new phosphorus alloys are more easily deposited than chromium and are very hard, corrosion-resistant, and bright. They should thus be of value for many of the applications in which chromium plate is now used to obtain a hard, wear-resistant surface or a decorative finish.

[6] For further technical details, see Electrodeposition of alloys of phosphorus with nickel or cobalt by Abner Brenner, Dwight E. Couch, and Eugenia Kellogg Williams, J. Research NBS **44**, 109 (1950), RP2061.

Plating baths for depositing the phosphorus alloys are rather simply prepared, consisting of common nickel or cobalt salts, such as the sulfate or chloride, to which is added phosphorous acid as a source of phosphorus in the deposit. The baths are operated at a low pH—between 0.5 and 1.5, depending on the composition. To maintain the desired acidity in the cathode film, the solution must be buffered. The Bureau has found that phosphoric acid is one of the best chemicals for this purpose. The plating baths are kept at 75° C or above, because at room temperature the cathode current efficiency is very low, and the deposits are weak. Current densities should be between 5 and 40 amperes per square decimeter. At the usual current density—about 10 amperes per square decimeter—the rate of deposition is fairly high, amounting to a few thousandths of an inch an hour.

The appearance of the deposits depends upon their phosphorus content. Alloys with less than 2 percent of phosphorus are usually smooth with a mat finish; but as the percentage of phosphorus increases, they become brighter, reaching a peak of brightness at a phosphorus content of about 10 percent. When such deposits are plated on a dull surface, they increase in brightness as they become thicker. As a result of the slightly dark cast of the high-phosphorus alloys, their reflectivity is 45 to 50 percent, as compared with about 60 percent for buffed nickel coatings.

When some of the phosphorus alloys are immersed momentarily in a solution of an oxidizing agent, such as ferric chloride, or made anodic in the plating bath, a jet black film is formed on the surface of the metal. This film is hard and adherent and appears to have possibilities for decorative use.



Photomicrograph of high-phosphorus nickel, 13% phosphorus (A); high-phosphorus cobalt, 10% phosphorus (B). Magnification × 250.

Composition of typical plating bath for depositing alloys of phosphorus with cobalt or nickel

Type of bath [a]	$NiSO_4 \cdot 6H_2O$	$NiCl_2 \cdot 6H_2O$	H_3PO_4 (100%)	H_3PO_3 (100%)	$CoCl_2 \cdot 6H_2O$
	g/liter	*g/liter*	*g/liter*	*g/liter*	*g/liter*
Low-phosphorus nickel	175	50	50	1.3	-----
High-phosphorus nickel [b]	150	45	50	40	-----
Low-phosphorus cobalt	-----	----	50	1.3	210
High-phosphorus cobalt [b]	-----	----	50	40	180

[a] It is very important that the pH of the baths listed be less than 1.0.
[b] The pH of the high-phosphorus baths should be raised to a value between 0.5 and 1.0 by adding nickel or cobalt carbonate.

Photomicrographs of the low-phosphorus alloys show a columnar structure, whereas the high-phosphorus alloys are found to have a laminated or banded structure. X-ray diffraction patterns of the high-phosphorus alloys show no crystalline structure. When heat-treated, the deposits develop a fine-grained structure instead of the large crystals characteristic of pure nickel or cobalt.

The hardness of the deposits as plated varies from 350 to 720 on the Vickers scale, increasing with phosphorus content. When the alloys are heat-treated at 400° C. they become much harder. For example, a heat-treated cobalt-phosphorus deposit containing about 10 percent of phosphorus reaches a hardness of over 1,100 Vickers, which is greater than that of electrodeposited chromium. Deposits that have been heated as high as 800° C and cooled are not appreciably softer than the initial deposit. However, the alloys have poor "hot hardness" and above a temperature of 600° C are softer than unalloyed nickel or cobalt.

Although the low-phosphorus alloys become ductile after heat treatment at 800° C, deposits containing more than 1 percent of phosphorus are generally brittle. Alloys with higher percentages of phosphorus are highly resistant to corrosion and chemical attack, exceeding in this respect the pure metals. Thus, in experiments at the Bureau the nickel alloy with 10 to 14 percent of phosphorus was attacked considerably less by hydrochloric acid than was pure nickel.

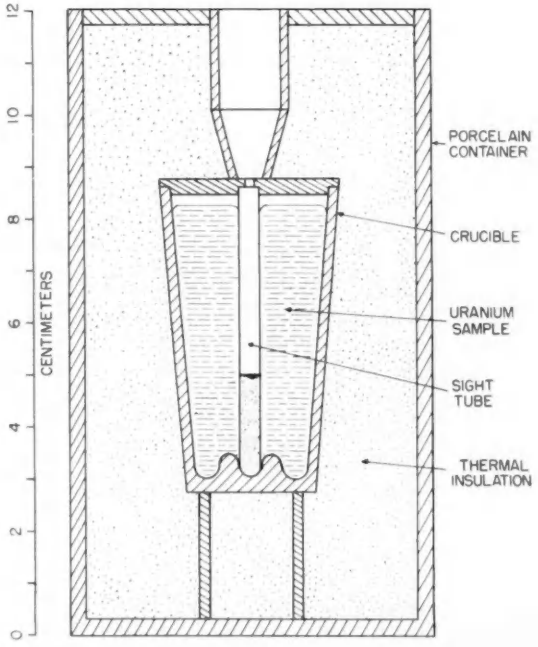
The pleasing appearance, ease of deposition, hardness, and corrosion resistance of the new alloys suggest the possibility of a number of commercial applications. Their use is indicated for gages, cylinder walls, piston rings, and other machine parts where resistance to wear is an important factor. In this connection, the more rapid rate of deposition as compared with chromium and the better throwing power of the plating bath should be of considerable advantage. Although the phosphorus alloys are not as white as bright nickel, the operation of the baths is much less critical than for proprietary bright nickel. The phosphorus alloys can be plated from a bath made up entirely of inorganic chemicals, whereas bright-nickel plating solutions must contain an organic brightening agent.

Freezing Point of Uranium Precisely Determined

The freezing point of uranium, previously known only in a very general way, has been measured [7] to a precision of 2 deg C by A. I. Dahl and H. E. Cleaves of the National Bureau of Standards. This high precision was attained by holding the metal at temperatures just above the melting point for several hours, which resulted in a decrease in the content of several impurities and an increase in the freezing temperature to a final constant value.

Until the recent developments in the field of atomic energy, uranium was of little practical importance and was not available in sufficient purity to permit accurate determination of its properties. Thus values for the melting point of uranium given in the literature ranged from 1,300° to 3,600° C. This wide spread in reported values was largely due to the fact that an oxidized casing or crust is formed on the surface of uranium when it is heated in the presence of most gases. The casing encloses the molten metal until temperatures far above

[7] For further technical details, see The freezing point of uranium, by Andrew I. Dahl and Harold E. Cleaves, J. Research NBS **43**, 513 (1949) RP2042.



Crucible assembly used at the Bureau for precise determination of the freezing point of uranium. The sight tube, a hollow enclosure serving as a black body, is immersed in a bath of the molten metal. The freezing temperature is measured by observation of the radiation from the black body with an optical pyrometer.

the melting point are reached. Obviously, the true melting point may be much lower than the temperature at which the molten material breaks through the casing.

When a quantity of relatively pure uranium became available as a result of the atomic energy program, the National Bureau of Standards undertook to develop a technique for accurate determination of its freezing point. Oxidation of the sample was prevented by use of a protective atmosphere of purified helium. It was found that when the metal was held just above the melting point for some time, impurities were removed by volatilization and migration to the top and side walls of the container. This procedure resulted in a purity of 99.99 percent and a consequent rise in the freezing temperature to a constant value of $1.133° \pm 2°$ C—about 5 degrees above the initial freezing temperature.

In the freezing-point determinations, the uranium was heated about 50° C above its melting point and then allowed to cool slowly. A hollow enclosure, or black body, was immersed in the uranium, and the freezing temperature was obtained by observing the radiation from the black body with an optical pyrometer during the time the metal was freezing. The uranium was melted in a high-frequency induction furnace. This type of heating caused stirring of the molten sample and thus provided a high degree of temperature uniformity throughout. It also minimized the possibility of contamination by the furnace elements.

Three samples of uranium were studied. Two of the samples were from the same extruded rod and had an initial purity of 99.94 percent. The third was cut from a cast ingot and was about 99.96 percent pure before heating. Major impurities were carbon and iron.

The three samples were melted in crucibles identical in size and shape, made of beryllia, graphite, and thoria, respectively. Uranium ingots weighing about 380 g were formed to the shape of the crucible by hot forging, and an axial hole was drilled in each ingot to accommodate the black body. Each sample was put in its crucible and mounted in an insulated porcelain container. This assembly was placed within a Pyrex glass enclosure, which fitted closely inside the water-cooled coils of the induction furnace. The Pyrex enclosure was flushed out with helium for about 2 hours before heating of the sample was begun, and a helium atmosphere was maintained during the actual heating.

Effect of Fuel Immersion on Laminated Plastics

Changes in weight and in the dimensional and flexural properties of laminated plastics immersed in three hydrocarbon liquids have been measured at the National Bureau of Standards as a means of evaluating the relative resistance of the laminates to different fuels. Constituting one phase of a continuing program on the properties of laminates for a wide variety of aircraft applications, the tests were designed to provide data needed in the preparation of specifications for those plastics found suitable for use as auxiliary (droppable) fuel tanks, radomes, instrument panels, and containers. The study,[8] conducted under the sponsorship of the National Advisory Committee for Aeronautics by W. A. Crouse, Margie Carickhoff, and Margaret A. Fisher of the Bureau's organic plastics laboratory, involved the determination of the effects on representative laminated plastics of cyclic and continuous immersion in three fuels.

The cyclic immersion test consisted of 10 alternate 24-hour periods of fuel-immersion and air-drying. Weight, dimensional measurements, and flexural determinations were made after reconditioning at 77° F and 50-percent relative humidity for 48 hours. For the continuous immersion test, duplicate sets of specimens were immersed for 7, 30, 90, 180, and 360 days. On one set of specimens weight, dimensional, and flexural measurements were made immediately after removal of the specimens from the fuel and on a second set, after reconditioning for 7 days at 77° F and 50-percent relative humidity. The fuels used for these tests were heptane (an aliphatic hydrocarbon), toluene (an aromatic hydrocarbon), and SR-6, a representative aircraft test fuel composed of blended aliphatic and aromatic hydrocarbons.

Dimensional and flexural strength changes are the principal properties to be considered in many of the aircraft applications. Most of the materials may be used for this purpose. Considering only the 360-day continuous immersion test, a cotton-fabric phenolic laminate exhibited the least changes in dimensions, and a paper phenolic laminate showed the smallest changes in flexural strength in the three fuels.

In all three fuels the weight changes of the majority of the laminates were less than 1.0 percent in the

Effects on the flexural properties of laminated plastics after immersion in different fuels were determined in a hydraulic testing machine using the specially designed variable-span flexure test jig (left). Load-deflection graphs were obtained on an autographic recorder operated by a plastics extensometer.

[8] For further technical details see forthcoming NACA Technical Note, Effect of fuel-immersion on laminated plastics, by William A. Crouse, Margie Carickhoff, and Margaret A. Fisher.

cyclic test, and did not exceed 1.5 percent after 360 days of continuous immersion. The largest weight changes were usually obtained in toluene. With very few exceptions, the length and width changes after either the cyclic or the 360-day immersion in the fuels did not exceed 0.1 percent. In both types of test the changes in thickness were not over 1 percent.

The best weight and dimensional stability in all three fuels in the cyclic test was observed with the glass-fabric unsaturated-polyester laminate. After the 360-day immersion test, the weight and dimensional changes were, in the majority of cases, equal to or higher for the samples that were tested immediately than for those that were reconditioned before testing.

The changes in flexural modulus of elasticity were, in the majority of cases, negative in the cyclic and the continuous immersion tests. In the cyclic test losses greater than 10 percent were shown only by the cotton-fabric unsaturated-polyester sample. After 360 days of immersion no losses greater than 10 percent occurred.

Since there may be appreciable differences in the properties of individual sheets taken from the same batch, in different batches made by the same manufacturer, and even in similar laminates made by different manufacturers, only general inferences about the different types of laminates can be drawn from these data. No single sample exhibited minimum changes in all of the properties, under the different conditions of immersion and with the three different fuels.

Description of materials

Type of laminate	Average thickness	Average density	Number of plies
	in.	*g/cm³*	
Lignin; paper	0. 128	1. 38	
Melamine; cotton fabric	. 145	1. 47	11
Phenolic; asbestos fabric	. 145	1. 49	5
Phenolic; cotton fabric	. 124	1. 35	7
Phenolic; rayon fabric	. 160	1. 35	6
Phenolic; paper	. 122	1. 42	54
Polyester; cotton fabric	. 147	1. 36	6
Polyester; glass fabric	. 125	1. 64	6

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Technical News Bulletin, volume **34,** number 5, May 1950. 10 cents.

CRPL–D68. Basic Radio Propagation Predictions for August 1950. Three months in advance. Issued May 1950. 10 cents.

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RP2082. Factors affecting the water vapor permeability of leather. Joseph R. Kanagy and Robert A. Vickers, III. 10 cents.

RP2083. Reduction of halomethanes with lithium aluminum hydride. Vernon H. Dibeler. 10 cents.

RP2084. Crystallization and second-order transitions in silicone rubbers. C. E. Weir, W. H. Leser, and L. A. Wood. 10 cents.

RP2085. Refractive index as a function of wavelength for sixty API–NBS hydrocarbons. Alphonse F. Forziati. 10 cents.

RP2086. Heats of combustion and formation of cellulose and nitrocellulose (cellulose nitrate). Ralph S. Jessup and Edward J. Prosen. 10 cents.

RP2087. Thermal and moisture expansion studies of some domestic granites. Arthur Hockman and Daniel W. Kessler. 10 cents.

RP2088. Separation of 2,3-dimethylpentane, 1, *cis*-3-dimethylcyclopentane, and 3-ethylpentane from petroleum. Augustus R. Glasgow, Jr., Charles B. Willingham, and Frederick D. Rossini. 10 cents.

RP2089. Interference methods for producing and calibrating end standards. Chauncey G. Peters and Walter B. Emerson. 15 cents.

RP2090. A note on the formation and structure of iron dendrites in a magnesium alloy. Harry C. Burnett, Jr. and Herbert C. Vacher. 10 cents.

Circulars

C485. Nickel and its alloys. 50 cents.

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